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Develop Technologies for Next Generation Natural Gas Vehicle Class 306 CNG Engines

Contractor

Cummins Westport Inc.
EmeraChem LLC.

Cosponsors

California Energy Commission
South Coast AQMD

Project Officer

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Background

The majority of heavy-duty vehicles in the South Coast Air Basin are powered by diesel engines that contribute significant NOx and particulate matter emissions. With an increasing number of trucks and other heavy-duty vehicles, the need for reducing emissions from these sources is critically important in meeting clean air goals. The AQMD has long recognized the adverse air quality and health impacts of diesel exhaust and has adopted several measures to promote the use of low-emission natural-gas vehicles.

The U.S. Department of Energy's Office of Heavy Duty Vehicle Technologies and the National Renewable Energy Laboratory initiated a program called the Next Generation Natural Gas Vehicle (NGNGV). The NGNGV program sponsors the development of heavy-duty natural-gas vehicles.

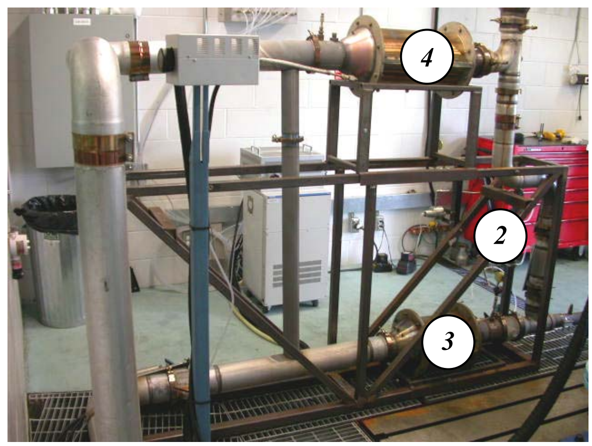
Project Objective

As part of the NGNGV program, the goal was to demonstrate 0.5 grams per brake-horsepower-hour (g/bhp-hr) NOx and 0.01 g/bhp-hr PM emissions from a lean-burn spark-ignition natura- gas engine. This would be achieved by reduction of in-cylinder NOx formation followed by conversion of NOx in an exhaust aftertreatment system. The program reviewed the potential of this approach and others to reduce NOx emissions toward 0.2 g/bhp-hr, improve full load performance, and increase overall system efficiency.

Technology Description

Targeting 0.5 g/bhp-hr NOx emissions

The 5.9 liter Cummins Westport B Gas Plus engine was developed to meet 1.2 g/bhp-hr NOx and 0.01 g/bhp-hr PM engine-out emissions. A NOx Storage and Reduction (NSR) system with by-pass flow during regeneration was identified as the emission control system best suited to achieve the program NOx targets. NSR systems work by first storing NOx in the catalyst. Once the NSR catalyst capacity is reached, it is regenerated by generating suitable conditions in the exhaust to release and reduce the NOx to nitrogen. In this case, the reformation of natural gas within the exhaust flow was developed as a novel method to regenerate the NSR catalysts.



The final prototype NSR emission control system hardware shown under test above included:

1. *Single bed NSR system with a by-pass route,*
2. *Two by-pass flow control valves,*
3. *14 liters of reformer catalysts, and*
4. *21 liters of NSR catalyst.*

The system components are identified by number in the picture above. Regeneration strategies were developed to work over the entire engine operating range.

Targeting 0.2 g/bhp-hr NOx emissions

Available technologies were screened in order to produce a manageable number of combinations. Three combustion types with appropriate emission controls were considered with three transmission types, as shown in the table below. Baseline vehicle simulation models were built and validated against published data and the nine selected system combinations compared. The systems were assessed on economical merit for transit bus and delivery van applications

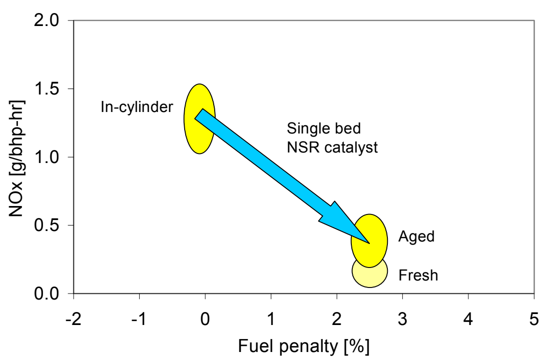
Combustion Type	+	*Aftertreatment*	*Transmission Options*
Lean-Burn SI (Spark Ignition)	+	NOx Storage & Reduction	Conventional
Stoichiometric SI with EGR	+	Three Way Catalyst	Continuously Variable Transmission
Direct Injection with Hot Surface Ignition	+	Selective Catalytic Reduction	Hybrid Electric Vehicle

Status

A prototype NSR system was commissioned in a test cell in November, 2002. Based on lessons learned while working with the prototype system, refinements were made. The modified system was optimized and demonstrated by the end of July, 2003. All work was completed to schedule and on budget. The final report is on file with complete technical details.

Results

The target of the program was to develop a system capable of delivering an aged composite NOx value of 0.5 g/bhp-hr over the AVL 8 mode cycle. An AVL 8 Mode composite 0.15 g/bhp-hr NOx level was demonstrated. Total hydrocarbon emissions were essentially unchanged and the fuel consumption increased by 2.5%.



NOx emissions of 0.15 g/bhp-hr were demonstrated with catalysts aged 60 hours; upon aging the same catalysts an additional 50 hours, the NOx system out increased to 0.30 g/bhp-hr. Although natural gas is an ultra-low-sulfur fuel, high temperature desulphations are required causing deterioration in NSR catalyst performance. Deterioration factor estimates indicate that the single bed system NOx levels should stabilize at approximately 0.6g/bhp-hr.

Benefits

It is estimated that around 1300 Cummins Westport lean-burn SI engines will be implemented within the South Coast Air Basin between 2004 and 2007. In total, the installation of the single bed NSR system would reduce the NOx emissions by two thirds or 2,264 tons over a 10-year lifetime. The average amortized cost of the NSR system is estimated as $14,864, giving a NOx cost effectiveness of $8,700 per ton. As the NSR technology matures the cost may be reduced, further increasing cost effectiveness.

Project Costs

The project was completed on time and within budget. A summary of the costs incurred over the course of the project are as follows:

	Actual	*Budget*
Project expenditure	$718,208	$707,000
CEC Funding	$374,174	374,174
SCAQMD Funding	$52,816	52,816
Match Funding	$318,208	307,000

Commercialization and Applications

Targeting 0.5 g/bhp-hr NOx emissions
The commercialization of the NSR system for heavy-duty applications is somewhat dependant on improving the catalyst durability. Further development such as control strategies for transient operation, system packaging and complexity reduction is also required.

Targeting 0.2 g/bhp-hr NOx emissions
The stoichiometric SI with EGR and a three-way catalyst in combination is best suited to meet the 0.2 g/bhp-hr NOx targets for transit bus and delivery van applications. Given a longer timeframe for development, the direct injection of natural gas with hot surface ignition (HSI) and SCR is competitive with the stoichiometric SI option. The benefits of the HSI system include increased part load efficiency, the potential to achieve higher BMEP, improved efficiency and reduced Green House Gas (GHG) emissions.